THE CLOUD RING ON BUFFALO MOUNTAIN, COLORADO.

By Prof. R. DEC. WARD, Harvard University, dated August 3, 1903.

In his Philosophy of Storms (1841, foot note, pp. XXIV and XXV), Espy quoted a letter from Caleb Williams, dated December 20, 1839, describing the curious cloud which he had observed in 1815 on the island of Hawaii. This cloud, due to the combined action of the diurnal sea breeze and the upcast valley breeze, was observed to form soon after the sea breeze set in, at about 9 in the morning, and later surrounded "The lofty conical mountain in that island, in the form of a ring, as the wooden horizon surrounds the terrestrial artificial globe." The mountain stood in bold relief, and from where the ship lay the summit could always be seen above the cloud. This reference to the cloud ring of Hawaii has often been quoted, and the cloud has become, as it were, a "stock example" of this kind of thing.

One of the writer's students during the past winter (Mr. L. V. Pulsifer, of the class of 1903, HarvardCollege), contributed to the discussions on clouds which were held by the class in meteorology, the following account of a cloud ring which he had observed in Colorado during the summer of 1901. As these are peculiarly interesting clouds, the description may be worth quoting in the columns of the REVIEW.

> Buffalo is a huge, roughly conical mountain, situated near the town of Dillon, Summit County, Colo. The general valley level at this point is about 8000 feet above the sea, and the mountain has a height of a little over 14,000 feet. I spent the summer of 1901 at Dillon, and on hot, still days noticed the formation of a cloud ring on Buffalo. This ring appeared at about noon, and was always at about the same height on the mountain side, roughly between timber line and snow line. The ring was not always perfect, but there was usually an incomplete ring even when the whole circuit was lacking. On the days when the ring was incomplete, the patches of cloud which did form were over the snow-filled gulches on the mountain side. During the middle of July and the first part of August the ring was best shown. * * * I do not recall whether this cloud ring ever reached a sufficient size to cause precipitation. It usually disappeared late in the afternoon.

ON CURVES REPRESENTING THE PATHS OF AIR IN A SPECIAL TYPE OF TRAVELING STORM.

By W. N. SHAW, Sc. D., F. R. S., Secretary of the Meteorological Council, dated August 25, 1903.

The instantaneous motion of air in a traveling storm may be regarded as approximately tangential to a series of concentric circles described about the barometric minimum as centre and representing isobaric lines. In any actual case there may be more or less "incurvature" of the air so that the lines of instantaneous motion are spirals instead of circles, and cross the isobars inwards. Moreover, in reality the isobaric lines themselves may be only more or less rough approximations to circles.

If the center of the storm (the barometric minimum) travels, the actual path of an isolated mass of air will be that described by a point which rotates with appropriate incurvature about a moving center. The real path will thus be a curve of no simple type and it will vary according to the speed at which the center travels. It can not be arrived at by superposing upon a simple rotational or spiral motion, a motion of translation equal to that of the center, because such superposition would alter the distribution of instantaneous velocities which represents the real instantaneous motion.

It is not difficult to calculate the actual paths for a special type of traveling storm making certain assumptions as to the velocities of the wind in different parts of the storm and the velocity of the center. As there are two kinds of motion to be considered, namely, that of the center, and that of the air masses, I propose, in order to avoid confusion, to limit the use of the word path to the motion of the center and to call the lines along which air travels "trajectories" of air.

The special case I propose to deal with is that in which the speed of the air is uniform over the area of the storm, although the direction varies from point to point. I shall also suppose the isobars to be true circles and the wind directions tangential to the isobars. Lastly the center will be regarded as describing a straight path with the same speed as the wind at any point. Whether this ideal state of things represents a possible reality is a matter for subsequent consideration.

Upon the hypothesis laid down, a "trajectory" is the curve described by a point rotating with uniform linear speed about a center moving with the same speed in a given direction. Take the path of the center as the x-axis of Cartesian coordinates and denote by θ the angle between the tangent to the trajectory and the positive direction of the path. The expression of the kinematical conditions must represent the fact that the center of curvature lies on the axis of x and moves along it with the same speed as the point along the trajectory. Expressing this condition we get the equation

$$y \sec^2 \theta \frac{d\theta}{ds} + \sec \theta = 1.$$

The same equation is obtained by equating the step along the curve to the step of the foot of the normal along the axis. Integrating the equation we get

$$y = \frac{c \cos \theta}{(1 - \cos \theta)},$$

c being an integration constant.

This equation represents a curve (see fig. 1) with a double

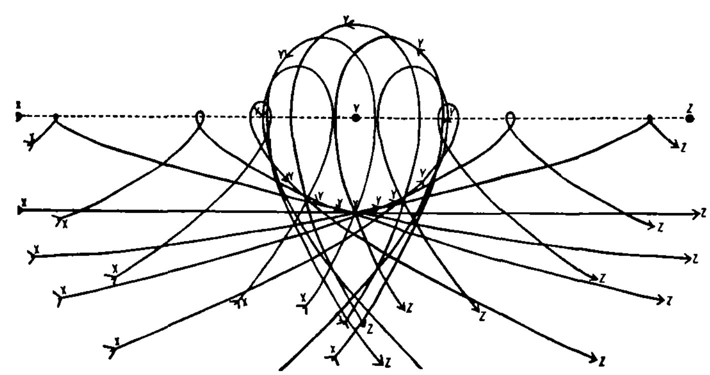

FIG. 1.—Calculated trajectories for the motion of air in a traveling circular storm when the velocity of the center is numerically equal to the wind velocity (assumed uniform) in the storm. XX. Initial positions of a series of particles and of the storm center. YY. Simultaneous position of the same particles when they lie on a circular isobar. ZZ. Final positions of the same particles and of the storm center.

point and a symmetrical loop above it. Taking a to be the ordinate of the top of the loop ($\theta = 180$), we get $c = -2a$ and $y + 2a \cos \theta / (1 - \cos \theta) = 0$ as the equation to the curve.

Substituting for $\cos \theta$ and integrating again we get

$$(a - y)\ (2a + y)^2 = 9\ ax^2$$

for the Cartesian equation of the curve when the axis of y is the line of symmetry of the loop.

The series of curves thus obtained for the trajectories is that represented in fig. 1; the intercepts on the axis of x are $\pm 2 / 3a$, and on the axis of y, a, and $2a$, representing the top of the loop and the double point, respectively. The curves of the family are similar in shape and are derivable one from the other by altering proportionally all linear dimensions. The one exception is the limiting case when $a = 0$ when the curve becomes a straight line parallel to the axis of x at an arbitrary distance from that axis and would represent the obvious result of a wind traveling parallel to the path of the storm at a fixed distance from the path.

It will thus be seen that the trajectories of air forming a revolving storm under the conditions described are widely different from the circular form represented by the isobars and do not even approximate to the spiral motion generally assumed under such circumstances to represent the course of the air supplying the storm.

The relation of the trajectories to the moving center of the storm may be most easily considered by reference to the particle which moves parallel to the path and always occupies a position on the diagram immediately under the instantaneous center. The trajectories represented in fig. 1 are those of particles which will for one instant form a series of points, Y, on a circular isobar when the storm center reaches the appropriate position, also denoted by Y. Their motion will then be tangential to the circle. The simultaneous *initial* positions of these particles and the corresponding position of the storm center are denoted by X and the final positions of the same particles on the diagram are denoted by Z, the corresponding position of the storm center being also marked with the same letter. Supposing that these lines represent the trajectories of air in a real storm, and, further, for the sake of clearness, that the storm center travels from west to east, it is evident that the following conclusions may be drawn:

1. The more central area will be fed by wind with directions from south-southwest to west, passing to a region in front of the storm center.

2. When the storm center has passed, corresponding winds will blow out from behind the center with directions from west to north-northwest.

3. The winds from the remaining directions will be comparatively transient in any locality, as the changes take place with great rapidity. These winds are represented by the loops of the curve.

4. No air is taken into the storm area from the northern side of the path.

5. There is a great convergence of winds behind the center to the two points in the line of the "trough" of the storm. This convergence is associated with corresponding divergence in front of the trough and apparent crossing of the trajectories at the trough itself.

It is to these characteristics that we must look in deciding whether this ideal state of things represents the circumstances of any actual storm. For this purpose it is necessary to construct the actual trajectories of air from weather maps for a real storm. Generally speaking, weather maps are only drawn for such widely separated intervals that there is not enough information for the construction of the trajectories. If, however, the records from a sufficient number of automatic instruments are available intermediate maps can be drawn. This has been done in the Meteorological Office for every third hour during the passage of the storm of February 26–27, 1903.

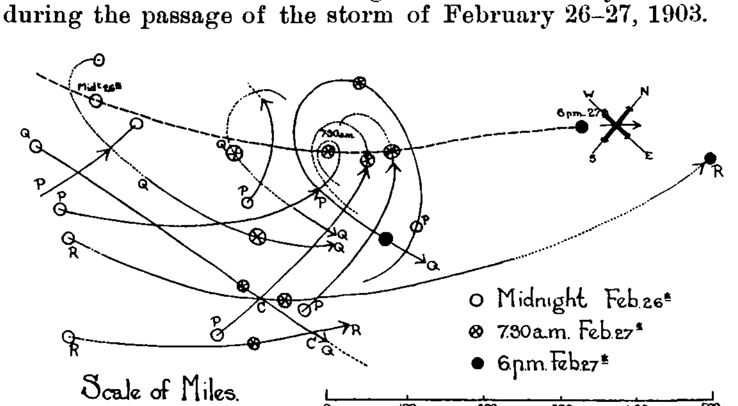

FIG. 2.—Trajectories of air in the storm of February 26–27, 1903, derived from records of wind. Those parts which are added by extrapolation from isobaric distribution are dotted. Path of center, - - - - - - - - - P, Trajectories of air passing to the front of the center. Q, Trajectories of air leaving the rear of the storm. R, Trajectories of air approximately parallel to the path of the center. C, Points of convergence and divergence on the trajectories parallel to the path.

The trajectories constructed from the recorded directions and velocities of the wind bear such a relation to the path of the center that the applicability of the kinematical reasoning here employed is quite unmistakeable. The material is of course not perfectly complete, but so far as it extends each of the characteristics enumerated above is represented with a fidelity quite unusual in the application of theoretical reasoning to the course of weather changes. A reproduction of some of the trajectories and of the path of the storm to the scale of the map is given in fig. 2. It will be seen that there is a strong general resemblance between the shapes of the curves in the two figures, the divergences are such as may be accounted for by supposing that the storm center was traveling rather more slowly than the wind. In comparing the two diagrams it is the shapes of the curves that should be regarded and not their actual position in the figure. The trajectories for the storm are taken from a series constructed by Mr. Lempfert from maps drawn by Mr. Brodie, of the Meteorological Office, and represent the paths of air producing conspicuous gales at various stations. Under the conditions of the question any one may be transferred parallel to itself along the line of the paths without serious modification, if required, to represent the path of the air reaching a particular point at a specified time, as in fig. 1. The points of resemblance to which attention should be directed are (1) the flow of air toward the front of the storm center, represented by the trajectories PP (fig. 2), from the directions within the quadrant S. to W. of the hypothetical case. As a matter of fact the storm in question traveled from southwest to northeast, roughly speaking, so that the specification of direction of wind requires adjusting when comparison is made with the hypothetical case. (2) The blowing out of air from behind the center, represented by the trajectories QQ. (3) The course of the trajectories RR, nearly parallel to the path, but converging slightly toward it as the wind gained upon the center. It is not necessary to suppose that the air moving along the P trajectories is identically the same as that moving along the Q trajectories; the former may rise in front of the center and be replaced by air which sinks behind it. (4) The convergence to points near CC, which are near the line of the trough at 7:30 a. m. and 9 a. m., respectively.

This convergence with its associated divergence in front of the trough raises an interesting meteorological question. It can only be accounted for by bringing the third dimension into consideration and supposing that the air rises when convergence takes place and descends from above when there is divergence. This would mean that the wind in front of the trough was supplied from the upper air while the motion behind the trough is in an upward direction. The latter must be associated with the production of rain. In this particular the agreement between the hypothetical and real trajectories is so close that the inferences to be drawn from it offer a promising field for inquiry into the physical changes associated with such storms. Into the investigation of these changes I do not propose to enter here. The primary conclusion I wish to draw is that the kinematical conditions represented by the hypotheses leading up to the equation

$$(a - y)\ (2a + y)^2 = 9ax^2$$

are sufficiently near to reality in some cases to identify a particular form of traveling storm.

Probably in nature three types of circular storms represented by a similar distribution of isobars about the center may be recognized. They are the following:

Type A. A stationary storm with spiral trajectories in which air is drawn from all sides. Type B. A storm traveling with a velocity approximating to that of the wind, as described above, in which air blows into the front of the storm and blows out from behind it. Type C. A storm moving comparatively slowly and therefore intermediate between types A and B.

Some important physical and meteorological significance must be attached to the indraft of air to points in front of the center and not to the center itself. The trajectories representing the inflowing air may be continued, in the particular case referred to, for distances beyond the region of circular isobars, and it would therefore appear that these strong currents are not primarily due to the previous existence of a center of disturbance, but to some more dominant cause which directs their trajectories to points successively approached by the center of circulation. It may be noticed that the direction of motion of the center with regard to the motion of these dominant winds stands in the relation of west to southwest or of southwest to south, and possibly the inblowing wind may be the determining cause of the motion of the barometric minimum.

The details of the storm of February 26–27, 1903, for which the trajectories were drawn are given in a paper read before the Royal Meteorological Society on June 17, 1903.

THE METEOROLOGICAL WORK OF THE EXPEDITION TO THE BAHAMAS.[1]

By Dr. O. L. Fassig, Section Director.

Leaving Baltimore June 1 on the two-masted schooner *W. H. Van Name*, with the scientific expedition sent out under the auspices of the Baltimore Geographical Society, I arrived at Nassau, Bahama Islands, on June 17. Storms, calms, and head winds marked the entire voyage outward, making it difficult to secure reliable instrumental records of the weather and temperature of the water. However, some interesting results were obtained which will be discussed in a separate report. Arriving at Nassau, a thermograph, barograph, hydrograph, and pluviograph were installed at the cable office by the courtesy of Mr. P. H. Burns, superintendent of the Bahamas cable. Mr. Burns also kindly attended to these self-recording instruments during my absence from Nassau, enabling me to obtain continuous records of the temperature, pressure, humidity, and time of occurrence of rain for a period of about thirty days, from June 20 to July 20. From the colonial records I had copied the monthly and annual mean values of meteorological observations for a period of five years.

During my short stay of two weeks at Nassau I succeeded in obtaining some interesting records of temperature, pressure, and humidity of the upper atmosphere by means of the Weather Bureau kite equipment, which I hope will also prove to be of some value in defining the vertical rate of change in atmospheric conditions in these latitudes. Light winds are the rule in the islands during the summer months, and it was only on a few occasions that favorable opportunities were presented for flying kites. However, five ascents were made to elevations varying from 3500 to approximately 8000 feet. The highest elevation was attained by the use of a launch. Steaming into the wind we were enabled to obtain a somewhat increased wind velocity. Apparently the wind velocity decreases rapidly after an elevation of 5000 to 6000 feet, it being difficult to detect any motion in the clouds above the lower cumulus layer. The results will be discussed at the earliest opportunity.

On the return trip, which was made under more favorable conditions than the outward voyage, an interesting series of observations of water temperatures was made from Nassau to Baltimore. While passing through the Gulf Stream the temperature of the water was noted every half hour or oftener. Good records were also obtained by means of the thermograph, barograph, and hydrograph.

In addition to the meteorological duties noted above, a magnetic survey of the islands was made. Declination, dip, and relative intensity were measured on the islands of New Providence, Hog, Watlings, Long, and Abaco. Observations made in past years in these islands included only the element of declination. A self-registering tide gage was also installed by me. The magnetic instruments and tide gage are the property of the United States Coast and Geodetic Survey.

The generous cooperation of the Weather Bureau with the Baltimore Geographical Society has been greatly appreciated by the director of the expedition, and due acknowledgments will be made in the official publications of the results of the expedition.

[1] Under date of August 1, Dr. O. L. Fassig reports his return to Baltimore from the Bahama Island, and gives some idea of the work accomplished.

CLIMATOLOGY OF COSTA RICA.

Communicated by Mr. H. PITTIER, Director, Physical Geographic Institute.

[For tables see the last page of this REVIEW preceding the charts.]

Notes on the weather.—On the Pacific slope the rain was uncommonly scarce, the month showing regular alternations of short periods of two, three, and four days of drought, separated by others of one and two days with moderate rainfall. On the 25th the rain began falling daily and the 28th, 29th, and 31st were marked by heavy showers. In San José, pressure and temperature were about normal, and the relative humidity a little less than the mean. Sunshine, 144 hours against a normal of 119. On the Atlantic slope also there was a scarcity of rain, excepting at a few stations at the foot of the Cordillera and at Turrialba and Paraiso in the Reventagon Valley, where the fall showed an excess. On July 10 a cyclone crossed the plains of Sta. Clara in an E–W direction, causing much damage to the banana plantations.

Notes on earthquakes.—July 23, 7^h 20^m a. m., slight shock NW–SE, intensity II, duration 3 seconds.

OBSERVATIONS OF SOLAR RADIATION WITH THE ANGSTROM PYRHELIOMETER AT ASHEVILLE AND BLACK MOUNTAIN, N. C.

By Mr. H. H. KIMBALL, Assistant Editor, Monthly Weather Review, dated July, 1903.

The Ångström compensating pyrheliometer, No. 28, used by Davis and Pierce[1] at Providence, R. I., from November, 1901, to September, 1902, was installed by me at Asheville, N. C., on November 8, 1902, in accordance with instructions received from the Chief of Weather Bureau. The point selected for its exposure was on the lawn just south of the Ravenscroft Hotel, near the crest of a ridge running north and south, with a slight dip to the south. The business portion of the town lay to the north and east, and as soft coal was almost the only fuel used the smoke at times became quite dense, particularly with light northerly winds.

The arrangement of circuits was as described by Professor Marvin in the MONTHLY WEATHER REVIEW for October, 1901, Vol. XXIX, p. 456. At first the galvanometer was suspended from the south side of the trunk of a large and nearly branchless locust tree, instead of from the tripod, as shown in fig. 1. Here an unobstructed view of the sun was had from the time it appeared above Beaumont Mountain, about a mile distant, some fifteen minutes after the time of true sunrise, until it set behind mountains nearly 20 miles distant, the tops of which were only one or two degrees above the true horizon. Winds above 20 miles per hour caused such annoying oscillations in the galvanometer that on December 22 it was moved to a post at the southeast corner of the hotel porch, where it was well protected from the prevailing northwest winds; but at noon and again at 4 p. m. the tripod support of the pyrheliometer had to be moved a few feet to avoid the shadow of shade trees.

On December 2, a Pickering polarimeter[2] loaned by Prof. E.

[1] See Monthly Weather Review for June, 1903, p. 275.

[2] For a description of this instrument see Proc. Amer. Acad. of Arts and Sci. N. S. Vol. XIII. Pp. 294–302.